Using Large Marine Ecosystems and Cultural Responsiveness as the Context for Professional Development of Teachers and Scientists in Ocean Sciences

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ABSTRACT

During 2010–2012, three professional development workshops brought together K–12 educators and scientists conducting research in the geographic and ecological context of Alaska's three large marine ecosystems (Bering Sea/Aleutians, Gulf of Alaska, and Arctic Ocean). Educators successfully applied new scientific knowledge gained from their interactions with scientists through the collaborative development of lesson plans that were place-based and culturally responsive to Alaska Native cultures. Over the course of the three workshops, we refined a model for incorporating cultural responsiveness into workshop design, employed an innovative systemic traditional knowledge framework, and developed a rubric to evaluate the lesson plans in terms of cultural responsiveness. Key factors that increased the impact of a single professional development workshop on the ability of the K–12 educators to produce culturally responsive lesson plans included (1) participation of experienced teachers as mentors, (2) opportunities for workshop participants to interact with community members and culture bearers, and (3) embedding the training within a longer-term program of curriculum development and professional development in a school district for which cultural responsiveness was a high priority. © *2014 National Association of Geoscience Teachers*. [DOI: 10.5408/12-403.1]

Key words: large marine ecosystems, K–12, curriculum, professional development, place based, culturally responsive, traditional knowledge, Alaska Native knowledge

INTRODUCTION

Some of the most significant ongoing ocean research in Alaska is conducted on a large-scale basis that integrates marine geoscience research into multidisciplinary studies organized geographically and ecologically by Alaska's three large marine ecosystems (LMEs): Gulf of Alaska, Bering Sea/Aleutians, and Arctic Ocean (Fig. 1). The major funders of this research include the National Science Foundation (NSF), North Pacific Research Board (NPRB), and National Oceanic and Atmospheric Administration (NOAA). They also encourage and support projects that integrate traditional ecological knowledge or local and traditional ecological knowledge with Western science. NPRB requires researchers who receive grant funding to engage in outreach and community involvement, and NSF requires researchers to articulate and implement the "broader impacts" of their research (NSF, 2007), which can take the form of broadening participation in science by underrepresented groups. Alaska's K–12 education system requires that curriculum and instruction in science meet Alaska state science standards (ADEED, 2006) and that all curriculum and instruction be culturally responsive to Alaska's diverse cultures by meeting Alaska state cultural standards (ADEED, 2006). This overlapping emphasis on outreach and education for local communities and Alaska Native cultures provided the foundation for the design of scientist–educator professional development workshops.

Three workshops took place between 2010 and 2012. Each focused on a different Alaska LME and was modified in response to conditions of the program and specific feedback through formative assessments. The purpose of this article is to share lessons learned and to reflect on the evolution of a model for professional development that supported place-based and culturally responsive instructional approaches to science education.

The primary partners in the design and implementation of all three workshops included the Alaska Center for Ocean Sciences Education Excellence (COSEE-AK), Alaska Sea Grant, and NPRB. Additional partners participated in planning and implementation of specific workshops: (1) Arctic Research Consortium of the United States (ARCUS) Polar Teachers Research and Education Collaborations (PolarTREC) program (Bering Sea and Arctic Ocean workshops), (2) the Monterey Bay Aquarium Research Institute's (MBARI) Educators and Researchers Testing

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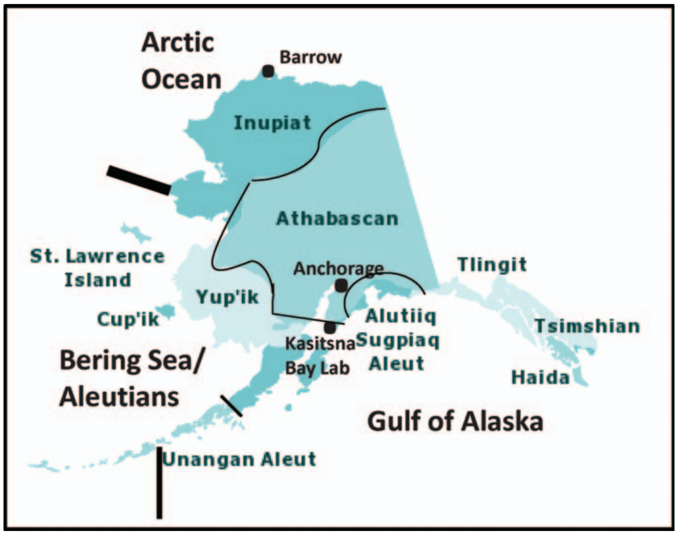

FIGURE 1: Map of Alaska showing boundaries of LMEs, Alaska Native cultural areas, and workshop locations.

Hypotheses (EARTH) program (Bering Sea and Gulf of Alaska workshops), (3) NOAA Teacher-at-Sea program (Bering Sea workshop), (4) Alaska Ocean Observing System (AOOS; Gulf of Alaska and Arctic Ocean workshops), and (5) North Slope Borough School District (NSBSD; Arctic Ocean workshop).

PURPOSE

We designed the workshops to provide a collaborative structure for scientists and educators to translate science content into lesson plans that were scientifically accurate, place based, and culturally responsive to Alaska Native cultures. The workshops were also designed as outreach opportunities for the ocean scientists to increase their interest and skills in translating their research for K–12 teachers and students. This article reports on lessons learned in relation to the development of the lesson plans. The impacts of workshop design features on scientists will be reported fully elsewhere.

CONTEXT

The design of the workshops required addressing a cultural disconnect between modern Western science and indigenous knowledge and ways of knowing. This disconnect contributes to an academic gap in science and a general failure for Alaska Native and Native American students to pursue higher education and careers in science (Semken, 2005) and science, technology, engineering, and mathematics (STEM) fields. Pandya (2012) described the disconnect between the norms and priorities of the research community and the values, aspirations, and cultures of many historically underrepresented communities as a key hurdle to broader participation. Research by Riggs (2005) and Levine et al. (2009) demonstrated that scientific careers and preparatory experiences are eschewed by indigenous students in favor of better known career paths or locally available opportunities. Snively and Corsiglia (2001) argued that indigenous cultures practice a science that interprets how the world works from their particular cultural perspective and that Western or modern science is just one of many sciences that need to be addressed in the science classroom. Western science thus functions as a subculture of Western culture (Ogawa, 1995; Aikenhead, 1996, 1997) and requires that students from a different subculture "negotiate a border crossing" from the "lifeworld" subculture in which they live to classrooms in which Western science is taught. Few do so successfully (Aikenhead, 1996).

The academic gap in science education is substantial for Alaska Native students who comprise 24% of all Alaska K–12 students (ADEED, 2012a). Most of these students are spread out over a large, rural area in small villages that range from 25 to 1,000 people. In these villages, a Native language is still a first language for many people, and many people still engage in subsistence hunting and fishing activities. In 2012, approximately half of Alaska's 53 school districts had a population that was more than 75% Alaska Native. During the 2011–2012 school year, the percentages of Alaska Native students scoring at advanced or proficient levels in statewide science assessments was consistently lower than all other ethnicities for grades 4, 8, and 10, ranging from 24% to 41% compared to statewide averages of 51% to 63% for comparable grade levels. The percentage of Alaska Native students scoring "far below proficient" was consistently higher, ranging from 40% in 4th grade to 26.5% in 10th grade, compared to statewide averages of 22.5% and 13.5%, respectively. The graduation rate for Alaska Native students was 53.9%, the lowest of all ethnic groups in Alaska (ADEED, 2012a).

Alaskan rural teachers and administrators are overwhelmingly not Alaska Native; only 5% were Alaska Native in 2012 (ADEED, 2012b). Teachers and administrators are often short term, staying in a village only 1 or 2 years. Hill et al. (2013) reported that (1) during the period 2009–2012, approximately one-third of teachers hired in Alaska were from outside the state and (2) turnover rates ranged from 10% to 60% during the 2011–2012 school year in districts where most students were Alaska Native. They also reported that despite a concerted effort in the University of Alaska system to train Alaskans as teachers, most of those who graduated with a teaching certificate preferred to seek employment in urban or road system districts rather than remote and rural districts and chose elementary education degrees rather than hard-to-fill positions in secondary math and physical science.

In response to a needs assessment survey concerning barriers to teaching about marine environments and climate change (Anderson and Plude, 2010), Alaska teachers identified their highest needs to be (1) teacher professional development to increase their science content knowledge and teaching skills, particularly in being culturally responsive to their Alaska Native students, and (2) connections with scientists. While urban teachers identified their greatest barrier to teaching about marine environments and climate change to be a lack of time, rural teachers identified the lack of Alaska-specific curriculum materials as their greatest barrier.

A 20-year Alaska Rural Systemic Initiative (AKRSI), begun in 1994, developed and implemented place-based education (grounded in local phenomena, culture, and issues) as a key instructional strategy in all subject areas for Alaska's regionally diverse Alaska Native students (Boyer, 2006). Semken (2005) promoted a similar place-

TABLE I: Characteristics of participants in the Alaska LME workshops.

	Bering Sea/Aleutians, October 2010	Gulf of Alaska, June 2011	Arctic Ocean, May 2012
Alaska K–12 Teachers	3	7	7
Alaska Informal Educators	0	5	0
Teachers From Other States	5	10	6
Scientists	15 (5 via videoconference)	6	14

based approach specifically for geoscience teaching as a strategy that could potentially enhance science literacy among Native American, Alaska Native, and other underrepresented minorities and bring them into the geoscience profession. The primary vehicle used by AKRSI (which subsequently became the Alaska Native Knowledge Network) to promote experiential, inquiry-based pedagogy has been the development of curriculum materials that guide teachers into the use of local environments and cultural resources as a foundation of all learning (Barnhardt, 2007). The success of the AKRSI approach for science and math education was demonstrated by higher science and math test scores, lower dropout rates, and an increase in the number of Alaska Native students choosing to pursue studies in the fields of science, math, and engineering for the 20 rural school districts that historically had the lowest student achievement levels in the state (ANKN, 1998; Barnhardt and Kawagley, 2010).

The successes of the AKRSI were instrumental in the adoption of Alaska state cultural standards for students (ADEED, 2006) and the development of standards and a rubric to evaluate culturally responsive educators (ADEED, 2012b).The focus of most of these cultural standards is on Alaska Native cultures not only because they are the cultures of many students but also because they are the heritage cultures of all Alaska students. The cultural standards for educators also address the need to acquaint students with both their local community and the world beyond their home community while facilitating their learning about other cultures. (Anchorage, the state's largest city, is particularly diverse, with close to 100 first languages spoken by students in the school district.)

Adapting curriculum and instruction to address the cultural standards has been challenging for Alaska school districts and for teachers, who often lack training, models, and Alaskan experience. The process is driven by strong interest of parents and Alaska Native community members in several rural school districts. The Arctic Ocean workshop provided the opportunity for the partners to work with the regional school district, the NSBSD, and their curriculum alignment program begun in 2010 that was responsive to the Iñupiaq culture of most NSBSD students. Curriculum alignment is being accomplished through the development of units and lesson plans that are cross referenced to both state and national subject matter standards and to elements of the Iñupiaq learning framework (ILF). Guided by Iñupiaq Elders and the school district's Iñupiaq Education Department, the ILF (NSBSD, 2010) was developed through meetings held in all communities in the school district. The Arctic Ocean workshop occurred during the third year of the district's 5-year professional development process that accompanied curriculum development and alignment.

The district and state emphasis in Alaska on improving science education for Alaska Native students is consistent with the national emphasis by NOAA, NSF, and other federal agencies to broaden participation by Alaska Natives as a group that is underrepresented in the sciences. This emphasis is also echoed in the evidence-based strategy in the next-generation science standards framework (NRC, 2012) that emphasizes the importance of cultural contexts that students bring to the classroom. The framework conceptualizes science learning as a cultural accomplishment and the inclusion of diverse cultural contexts as a means to address diversity and equity in science education. As described in the framework, students arrive in the science classroom with a "cultural fund of knowledge that can be leveraged, combined with other concepts, and transformed into scientific concepts over time." Research cited in the framework supports the effectiveness of educational practices that build on the prior interest and identity of students and recognizes that diverse cultural knowledge and skills are assets to build upon to address inequities in the availability of educational resources and instructional supports.

METHODS

Setting

The locations of the workshop are shown on the map (Fig. 1). The Bering Sea and Arctic Ocean workshops were held in Anchorage, Alaska, and Barrow, Alaska, respectively; the Gulf of Alaska workshop was split between 1 day in Anchorage and 4 days at the NOAA/University of Alaska Fairbanks (UAF) Kasitsna Bay Marine Laboratory near Homer, Alaska. During all workshops, participants had access to presentation technology, the Internet, and workspaces for the full group and small-group breakout sessions.

The three LMEs differ in the mix of rural and urban communities along their shorelines and the cultural diversity of the bordering regions (Fig. 1). Coastal communities along the Bering Sea and Arctic Ocean coasts are rural. A single Alaska Native culture predominates in different areas of these regions—Yup'iit along the Bering Sea, the Unangan/Aleut in the Aleutian Islands, and the Iñupiat along the Arctic coastline. In contrast, the Gulf of Alaska includes the urban coastal communities of Anchorage and Juneau and spans several Alaska Native cultural areas: Alutiiq/Sugpiaq, Tlingit, Tsimpsian, and Haida.

Target Audiences

The target audiences for the workshops were (1) scientists engaged in marine ecosystem research in Alaska, (2) Alaskan K–12 educators in communities within each respective marine ecosystem, and (3) teachers from other states who had participated in research experiences through the PolarTREC or NOAA Teacher-at-Sea program or who had experience teaching inquiry-based science (Table I).

TABLE II: Affiliations of scientist participants in the Alaska LME workshops.[1]

Scientist Affiliation	Bering Sea Workshop	Gulf of Alaska Workshop	Arctic Ocean Workshop
University	8 (6 universities)	3 (1 university)	6 (3 universities)
Federal agency	2 (NOAA, Smithsonian)	1 (NOAA)	1 (NSIDC)
State agency	0	0	1
Local agency	0	0	3
Nonprofit organization	1	1	0
Private consultant	1		2
Funder (NPRB)	3	1	1
Totals	15	6	14

[1]NSIDC = National Snow and Ice Data Center.

Scientists

Thirty scientists were invited to participate in the workshops based on their involvement in research in the Alaska LMEs and demonstrated outreach skills and interest. These skills and interests were evaluated by the science outreach specialists on the planning team who were responsible for reviewing their research proposals and reports. An additional five scientists were invited to contribute local science content. For each workshop, the selection of researchers and the agenda design reflected the desired coverage of the components of a marine ecosystem study (e.g., physical oceanography, lower trophic levels, higher trophic levels, human role in the ecosystem, and ecosystem modeling). The scientists were affiliated with several institutions and agencies including UAF, University of Washington, University of Maryland, University of Georgia, University of British Columbia, Columbia University, NOAA, the North Slope Borough Wildlife Management Department, MBARI, NPRB, and three private consulting companies. Attention was given to gender balance, which was more successful for the Gulf of Alaska workshop (3 males, 3 females) and the Arctic Ocean workshop (9 males, 5 females) than for the Bering Sea workshop (11 males, 2 females). Table II summarizes the scientist affiliations represented in each workshop.

Educators

Thirty-eight K–12 science teachers and five informal educators were invited to participate in the workshops, including Alaska K–12 teachers and informal educators from communities within the geographic area of the LME and from states other than Alaska (Table I). The primary selection criteria were a demonstrated interest in marine education and experience with inquiry-based teaching. Experience with place-based or culturally responsive education was also a desired trait in the selection of Alaska educators but was not always present in teachers interested in attending. Alaskan teachers were recruited and selected based on recommendations from informal educators and school administrators. Informal marine educators were invited to participate in the Gulf of Alaska workshop because it was the only geographic area in Alaska where they provided a substantial amount of K–12 marine science education through field trips and onsite programs at aquariums, museums, and science centers. Teachers from outside Alaska were invited to participate based on past participation in a PolarTREC or NOAA Teacher-at-Sea research project in the Bering Sea or Arctic Ocean or, for the Gulf of Alaska workshop (which had no comparable pool of teachers), through an application process conducted by the MBARI EARTH program. Each workshop had a mix of Alaska educators and teachers from outside Alaska and coverage of elementary-, middle-, and high-school grade levels.

The Alaskan educators who participated in the workshops taught in rural communities, with the exception of one university-based educator who taught preservice teachers in Fairbanks. Rural Alaskan teachers who participated in the Bering Sea and Arctic Ocean workshops taught in communities where the Alaska Native population ranged from 51% to 96% of the total population (ADCED, 2010). Due to the selection of communities where informal education institutions were present, Alaska teachers and informal educators who participated in the Gulf of Alaska workshop were from communities (Homer, Seward, Kodiak, Cordova, Valdez, and Sitka) where Alaska Native students were present but not the majority of students. However, the informal education programs serve schools in smaller communities with predominantly Alaska Native students. We were not successful in recruiting Alaska Native teachers from among the small pool of Alaska Native science teachers in the target communities. Although attention was paid to achieving gender balance, we were not successful (39 females and 4 males across all three workshops).

Communities

We were selective in recruiting Alaskan teachers and informal educators from specific communities within each marine ecosystem, using a different criterion for selecting the target communities for each workshop. We selected teachers from Emmonak, St. Paul, and Nome to participate in the Bering Sea workshop because these communities were engaged in the NPRB/NSF Bering Sea ecosystem study. For the Gulf of Alaska workshop, we selected teachers from Homer, Juneau, Petersburg, Seward, Sitka, Kodiak, and Valdez, within the area of the Gulf of Alaska ecosystem study (in the planning stages at the time of the workshop), because each of these communities provided an opportunity for partnerships between teachers and informal marine education institutions. NPRB was also in the planning stages for an Arctic ecosystem study at the time of the Arctic Ocean workshop, but other efforts to coordinate and integrate Arctic research have been under way for decades. Here, we followed the lead of the NSBSD administrators in recruiting

TABLE III: The conceptual framework for science content and essential questions for Alaska marine ecosystem scientist–teacher workshops.

Conceptual Framework for Science Content	Essential Questions for Science Education
Bering Sea Ecosystem Study Workshop	
Physical forcing affects food availability.	How do physical processes affect and control the availability of food for organisms at different levels in the food web?
Ocean conditions structure trophic relationships.	How do ocean conditions structure food webs from "the bottom up?"
Ecosystem controls are dynamic.	How does the Bering Sea ecosystem change in response to changes from "the bottom up" or "the top down?"
Location matters.	How does "place" (location in the ecosystem) matter to the survival, diversity, and abundance of life in the Bering Sea ecosystem?
Commercial and subsistence fisheries reflect climate.	How will changes in ocean conditions affect the abundance and distribution of fisheries?
Gulf of Alaska Ecosystem Workshop	
The Gulf of Alaska ecosystem study gauntlet hypothesis: The primary determinant of year-class strength for marine groundfishes in the Gulf of Alaska is early life survival.	What factors determine the survival of five species of Gulf of Alaska fish during their first year of life and their survival to adulthood?
Predicted increases in ocean acidification and ocean water temperatures will substantially change marine food webs at high latitudes. The effects on individual species will be variable; there will be "winners" and "losers."	How does the chemistry of the ocean change when the rate of carbon dioxide absorption increases?
	How will changes in the acidity of the ocean chemistry or in ocean water temperatures affect marine life in the Gulf of Alaska?
Improved technology produces more precise mapping of the ocean floor.	How do scientists map the bottom of the Gulf of the Alaska?
Arctic Ocean Ecosystem Workshop	
Physical and biological processes of the Arctic Ocean	How do the physical processes of the Arctic Ocean influence or force biological processes?
Potential for change in Arctic Ocean marine life	How will changes in the physical and chemical conditions in the Arctic Ocean affect marine life?
Resiliency and change for Arctic peoples	What does it mean to be resilient to environmental change? How do Arctic people demonstrate resilience?
Careers in Arctic Ocean science	No corresponding essential question

teachers who were expected to integrate the training into the development of the district science curriculum. All but one teacher who was selected taught in Barrow, the regional center with the largest number of students and the school district office; the remaining teacher taught in the village of Pt. Hope.

Workshop Design

The workshop was designed by a team of science outreach specialists and K–12 marine education specialists from partner organizations. Those of us affiliated with NPRB and COSEE-AK and the COSEE-AK project external evaluator participated in the planning of all three workshops and consulted with scientists with a broad knowledge of Alaska marine ecosystem research to determine science content. The other authors participated in the planning of one or two of the workshops by assisting with the recruitment and selection of participants or providing expertise in workshop design to facilitate scientist and teacher interactions. The cultural components of the workshops were designed in consultation with cultural experts for Alaska Native cultures represented within each LME.

Scheduling

Availability of scientists and teachers was a large constraint on workshop design, which affected the ratio of scientists to educators and the duration of participation by scientists in the workshop. Rural Alaska teachers were generally unavailable during the summer, and researchers were often unavailable during field seasons that stretched from May to October and at times during the winter because of teaching commitments or participation in science conferences. During the school year, school district requirements to pay the costs of substitute teachers for teachers participating in the workshops added to workshop costs. We experimented with October for the Bering Sea workshop, with late June for the Gulf of Alaska workshop, and with late May for the Arctic Ocean workshop. The daily schedule of the Arctic Ocean workshop was modified to accommodate the participation by community members who were opportunistically engaged in subsistence activities of whaling and waterfowl hunting.

Science Content and Curriculum Development Framework

We used hypotheses and research topics that unified current ecosystem-scale research to frame the science

content for the workshops. We then translated these hypotheses and into essential questions (Table III) to focus and unify science curriculum development in accordance with the "understanding by design" model developed by Wiggins and McTighe (2005). Major hypotheses were available for large-scale Bering Sea and Gulf of Alaska LME studies (NPRB, 2008, 2010). The Gulf of Alaska study, however, was at a conceptual stage at the time of the workshop, so the topics of ocean acidification and sea floor mapping technology were added as the subjects of major ongoing research in the Gulf of Alaska that had produced results and datasets. For the Arctic Ocean workshop, we organized the science content and essential questions by topic following discussions with Arctic scientists about current high priorities for Arctic research and with community and cultural experts about research topics that were most relevant to Arctic and Iñupiaq communities.

Integration of Cultural Components

In addition to the LME research context, an innovative design element of the workshops was the integration of cultural components to guide the development of lesson plans that were culturally responsive to Alaska Native students. For the first two workshops, we provided an introduction to the Alaska Native cultures that relied on the Bering Sea or Gulf of Alaska marine ecosystems through anthropologist-guided tours of the exhibits and resources of the Smithsonian Arctic Studies Center located in the Anchorage Museum. The participants in the Gulf of Alaska workshop had a second tour of a Sugpiaq tribal museum in Seldovia, the village close to the Kasitsna Bay Marine Laboratory.

In addition to museum staff who led tours during the Bering Sea and Gulf of Alaska workshop, other cultural experts and social scientists were invited as presenters and participants. For the Bering Sea workshop, presenters included Ray Barnhardt, director of the UAF Center for Cross-Cultural Studies, to speak about culturally responsive teaching strategies and resources and Henry Huntington, a social scientist involved in the Bering Sea ecosystem study and a specialist in the integration of traditional ecological knowledge with Western science. For the Gulf of Alaska workshop, the Seldovia Sugpiaq tribal environmental educator was a presenter, participated in discussions, and led the tour of the tribal museum.

The Arctic Ocean workshop had the greatest number of cultural components that were well integrated throughout the workshop. The decision to have the workshop in Barrow, rather than in Anchorage, provided opportunities to invite local natural and social scientists and community members who were Iñupiaq Elders and other cultural experts to participate. The agenda combined presentations by scientists, school district administrators, and Inupiaq cultural experts prior to beginning collaborative work on the lesson plans. Presentations by Inupiaq cultural experts were by (1) an Iñupiaq Elder and educator who had previously summarized the history of education on the North Slope (Okakok, 2010) and participated in development of the ILF, (2) an Iñupiaq Elder who was a member of the school board, (3) an Iñupiaq educator who was director of the NSBSD Iñupiaq Education Department, and (4) an Iñupiaq wildlife manager who spoke about himself as a third-generation whaler and participant in arctic research. We coached visiting and local scientists on tailoring their presentations to the teacher audience. Local scientists included an anthropologist and a marine mammal biologist. All science presentations, organized into panel discussions by topic, were followed by interactive small-group sessions to discuss how the science might be applied in classroom activities.

Local scientists also provided tours of the area, including the labs and collections managed by the NSB Wildlife Management Department. A number of scientists and teachers spent time exploring the Arctic sea ice and the town of Barrow. The timing of the workshop coincided with the spring whaling season, which provided opportunities for teachers and scientists to interact with community members who were processing their harvest. Community members shared their whale meat with workshop participants. For many, this was their first opportunity to participate in this traditional activity.

Collaborative Products

The tangible outcome of the workshop was a collection of standards-based science lesson plans and other resources relevant to each of the LMEs. This expectation was introduced during the recruitment of participants and used to frame the workshop. Participants were provided with a lesson plan template and references and links to national and state science standards and, in the case of the Arctic Ocean workshop, to the ILF. An Iñupiaq educator joined the Arctic Ocean workshop planning team to facilitate the use of the ILF as a guiding document for lesson plan development and curriculum alignment with cultural standards.

Scientists were involved in the final review of the lesson plans to ensure the scientific content was accurate. The materials were posted to the Internet to be widely available.

Evaluation Methods

Changes in Teacher Knowledge and Confidence

Researchers have theorized that the quantity of professional development (and its content) has effects on teaching practice and classroom culture and is an important predictor of student outcomes (Desimone et al., 2002; Banilower et al., 2007; Yoon et al., 2007). Studies that have looked directly at the effect of professional development on student learning, however, are few (Yoon et al., 2007; Blank and de las Alas, 2009) and would require rigorous evaluation methods that we lacked the resources to pursue. We instead focused our evaluation efforts on teacher learning, confidence, and application of scientific knowledge and teaching strategies in accordance with guidance in the National Science Education Standards (NSESs) (NRC, 1996) for the characteristics of quality professional development. In addition, we evaluated teacher learning, confidence, and application of culturally responsive teaching strategies and included scientists in the evaluation of the workshop and its products during the Arctic Ocean workshop.

The evaluator conducted formative assessments during each workshop through online end-of-day surveys of the educators. Each day, the questions were specific to the participants' understanding about the big, key ideas from individual presentations or activities of the day provided by educators, scientists, or cultural experts. Participant responses were used by the workshop facilitators to improve activities and to determine whether more information was needed for educators to assimilate key concepts delivered by scientists.

A collective review by the planning team was conducted at the conclusion of the first two workshops to refine the workshop model for the next workshop. A summative assessment was conducted for the Arctic Ocean workshop via online pre- and postworkshop surveys of the participating teachers. For each of the workshop topics, they were asked to self-assess their changes in knowledge and confidence in teaching those topics. They were also asked to self-assess their changes in knowledge about integrating traditional knowledge into their science teaching and their confidence about being able to do so.

Lesson Plans

After teachers presented their lesson plans on the last day of the Arctic Ocean workshop, scientists were asked, "Do you have any specific feedback about any of the lessons shared this afternoon?" The question was added to the end-of-the-day survey following the teacher presentations of the lesson plans.

We evaluated the lesson plans with respect to whether (1) the science content reflected specific content presented by scientists, was consistent with the science-related essential questions, or both; (2) a place-based teaching strategy was present; and (3) the lesson plan was culturally responsive. The evaluation of science content and a place-based teaching strategy involved a review for the presence or absence of each trait. To evaluate the science content, we relied on the essential questions for each workshop and our observations of scientist presentations either during the workshop or later by videotape. To evaluate the presence of place-based strategies, we relied on our professional experience with the application of these strategies in other contexts. To evaluate cultural responsiveness, we used a modified version of the rubric developed by ADEED (2012b) for evaluation of culturally responsive educators (Table IV). The changes we made modified the evaluation tool from one recommended for use to evaluate the curriculum and instructional practices of a school staff over a long period to one that could evaluate performance within the scope of the project. We reviewed lesson plans for the presence of specific traits described in the rubric elements and the level of accomplishment for the element (Level I, emerging; Level II, developing; Level III, proficient; and Level IV, exemplary). We eliminated rubric elements or levels of accomplishment if they required the observation of classroom practice or participation in the community over time, both of which were beyond the scope of the project. In the case of the Arctic Ocean workshop, the essential questions developed for the ILF were also used to assess cultural responsiveness.

Cultural Responsiveness of Workshop Design and Implementation

As a summative evaluation of the three workshops, we evaluated the performance of the workshop designers and facilitators as culturally responsive educators, using the same traits and levels of accomplishments in the rubric.

Impacts of the Workshop on Scientists

The COSEE-AK project external evaluator conducted online postworkshop interviews of the scientists who participated in the Bering Sea and Gulf of Alaska workshops. During the Arctic Ocean workshop, she included scientists in the end-of-the-day surveys and added questions that scientists were asked to assess their responses to educational activities. Following the presentations by teachers on the last day of the Arctic Ocean workshop, they were asked, "One of the lessons presented—the Black Guillemot activity—involved a modeling of a lesson as might be presented to students. Was that helpful and if so, why?" They were also asked to reflect on what they had learned about K–12 education through additional questions on the final end-of-the-day survey by responding in an open-ended way to the statement "We want to know what concepts or ideas about education, working with teachers, and creating lessons plans that you learned (or gained appreciation for) as a result of this workshop" and to the question "Did you feel your time was well spent?" The results of the scientist assessments will be reported fully elsewhere, but some of their responses are highlighted in the Lessons Learned About Workshop Design section.

Limitations

The lesson plans were developed from new science information in a relatively short period. The use of the lesson plan products to assess elements of teacher practice does not reflect longer-term changes in practice that might result in the future from the additional support provided by school districts, such as the NSBSD, in their continuing efforts to support teachers in developing lesson plans into units aligned with a cultural framework.

RESULTS

Change in Content Knowledge of Educators

Only the Arctic Ocean workshop afforded the opportunity to assess changes in teacher knowledge and comfort with a pre- and postprogram assessment. Using a scale of 1 (really don't know) to 10 (completely knowledgeable or confident), teachers completed a self-assessment on a total of 15 questions before and after the workshop. The results of the t-test showed positive, statistically significant changes in knowledge with six of eight content areas (Table V) and increased confidence in teaching five of seven content areas (Table VI).

Evaluation of Lesson Plans

Thirty-five lesson plans and activities were developed through the workshops. These lesson plans were developed by individuals or self-organized groups that included teachers, scientists, informal educators, or a combination of these individuals.

Lesson plans are posted on the Web at the following locations:

- Links to files of all lesson plans: www.coseealaska.net/resources
- Arctic Ocean Resource Collection (includes PowerPoint presentations by 13 scientists): www.polartrec.com/collections/arctic-ocean-ecosystem
- Bering Sea Resource Collection of lesson plans and other regional resources: www.polartrec.com/collections/bering-sea-ecosystem
- Gulf of Alaska lesson plans: www.mbari.org/earth/2011/schedule11.htm

TABLE IV: Rubric to evaluate the cultural responsiveness of lesson plans and workshop design.[1]

Educators Who Meet This Standard	Level I: Emerging (understanding or beginning to recognize)	Level II: Developing (understanding with limited development or partial implementation)	Level III: Proficient (functional and operational level of development and implementation)	Level IV: Exemplary (fully and fluently engaged in implementing, mentoring, and collaborating)
Standard A. Culturally responsive educators incorporate local ways of knowing and teaching in their work.				
A.1: Recognize the validity and integrity of traditional knowledge systems.	Acknowledges simple cultural activities.	Includes students' prior knowledge and skills through cultural activities.	Links students' prior knowledge and skills through cultural activities, language, ways of life, the arts, and traditional knowledge systems.	Integrates students' prior knowledge and skills through cultural activities, language, ways of life, the arts, and traditional knowledge systems.
A.2: Use Native Alaska Elders' expertise in their teaching.	Recognizes value of Elders' sharing expertise as guest speakers in the classroom.	Asks Elders to share expertise as guest speakers in the classroom, and connects Elders expertise with academic learning.	NA	NA
A.3: Provide opportunities and time for students to learn in settings where local cultural knowledge and skills are naturally relevant.	Recognizes and acknowledges local community events in the classroom.	Describes local community events and identifies classroom lessons and activities that intersect with these activities.	Incorporates local community events and relevant community members into classroom lessons and activities.	Integrates student learning in the community's natural cycle of people, ceremonies, and place into classroom lessons and activities.
A.4: Provide opportunities and time for students to learn through observation and hands-on demonstration of cultural knowledge and skills.	Provides opportunities for students to observe Alaska Native Elders and other local residents demonstrating their cultural knowledge.	Provides several opportunities for students to observe Alaska Native Elders and other local residents demonstrating their cultural knowledge.	Regularly uses Alaska Native Elders and other local residents in and out of the classroom to demonstrate cultural knowledge for students.	NA
A.6: Involve themselves in learning about local culture.	Identifies the important aspects of the local culture.	NA	NA	NA
Standard B. Culturally responsive educators use the local environment and community resources to link what they are teaching to the everyday lives of their students.				
B.1: Engage students in appropriate projects and experiential learning activities in the surrounding environment.	Observes the surrounding environment and local culture through community interactions.	Asks students, families, paraprofessionals, and other community members about seasonal activities and discusses these in class.	Links seasonal activities in and out of the classroom to content-area requirements.	NA
B.2: Use traditional settings such as camps as learning environments for transmitting both cultural and academic knowledge and skills.	Observes traditional settings and cultural activities where knowledge and skills are learned.	Acquires knowledge and skills that are learned in traditional seasonal and cultural activities that are practiced by the community.	Links traditional settings and/or creates replicas, practicing activities for cultural and academic learning settings.	Integrates curriculum for seasonal traditional activities, bridging cultural and academic components.
B.3: Provide integrated learning activities organized around themes of local significance and across subject areas.	Observes themes of local significance to the community.	Inquires about local themes in the classroom organized thematically by seasonal activities.	Supports student participation in local cultural activities, and applies those activities to content-learning activities.	NA

Application of Scientific Knowledge

As shown in Table VII, the teachers applied scientific knowledge gained in the workshop to the development of lesson plans. Bering Sea lesson plans focused on science content presented on important ecological attributes of the Bering Sea ecosystem, Bering Sea food webs, plankton, and the concept of water pressure at depth. Gulf of Alaska lesson plans focused on the science content presented on topics of

TABLE IV: Continued.

Educators Who Meet This Standard	Level I: Emerging (understanding or beginning to recognize)	Level II: Developing (understanding with limited development or partial implementation)	Level III: Proficient (functional and operational level of development and implementation)	Level IV: Exemplary (fully and fluently engaged in implementing, mentoring, and collaborating)
B.4: Demonstrate knowledge in relevant areas of local history and cultural traditions, including the appropriate times for certain knowledge to be taught.	Learns significant local history and cultural traditions from culture bearer.	Inquires about local history and cultural traditions, guided by the culture bearer.	Links the history of the local community, including historical timelines and stories of the people.	Mentors other educators on local history and cultural traditions, and uses the expertise of culture bearers.
B.5: Seek to ground teaching in a constructive process built on a local cultural foundation.	Learns about the cultural values of the community.	Describes and lists the local cultural values and illustrates how they apply to everyday life.	Links teaching and learning to local values.	Integrates cultural values into the curriculum.
Standard C. Culturally responsive educators participate in community events and activities in appropriate and supportive ways.				
C.2: Exercise professional responsibilities in the context of cultural traditions and expectations.	Recognizes professional responsibilities regarding content related to the local cultural content.	Identifies strengths and areas for improvement in his or her professional practice.	Seeks learning opportunities to improve practice.	Exercises professional responsibilities in the context of cultural traditions and expectations.
C.3: Make appropriate use of the cultural and professional expertise of other educators and their coworkers from the local community.	Recognizes and names local cultural and professional expertise of other educators or coworkers.	Identifies and uses the cultural and professional expertise of other educators or coworkers.	NA	NA

[1]NA = not applicable.
Adapted from ADEED (2012a).

ocean acidification; mapping the seafloor, seafloor features, and bathymetry; the life cycles and ecology of fish; and ecosystem interactions. The Arctic Ocean lesson plans were inclusive of science content presented at the workshop on bowhead whale ecology, Arctic Ocean food webs, Arctic Ocean conditions, sea ice dynamics in relation to ocean conditions, and the implications of the pattern of Arctic sea ice melt to arctic wildlife populations.

Place-Based Teaching Strategies

The use of a place-based teaching approach to the lesson plans was not uniform and, when employed, took three forms: (1) place based solely with respect to an Alaska LME, (2) place based but involving more than one site, including at least one within an Alaska marine ecosystem, and (3) place based but for a geographic area other than Alaska applicable to any site. Most Alaska educators used the first approach to develop lesson plans relevant to the marine ecosystem in which they lived. Most teachers from outside Alaska who had research experience in a particular marine ecosystem also developed lesson plans relevant to that ecosystem, which accounted for more Alaska-relevant lesson plans generated by teachers in the Bering Sea and Arctic Ocean workshops. Examples of lesson plans that included both place-based and culturally responsive elements are described in the next section.

Several teachers from outside Alaska used the second approach in developing their lesson plans, usually in collaboration with Alaska teachers to compare Alaska LMEs with other ecosystems or to include Alaska sites with sites in other geographic areas. Lesson plans involving comparisons included one that compared the ecology of bearded seals in the Bering Sea with monk seals in the Hawaiian Islands, one that compared aging techniques using otolith growth patterns for pollock in the Bering Sea with using local tree ring growth patterns, and one that compared data collected by students in Alaska and New York to consider the effects of Arctic sea ice patterns on the Arctic and Atlantic Oceans related to their connection by a global-scale current system. Examples of lesson plans that were not specific to Alaska but included Alaska marine sites involved the comparison of the underwater topography offshore of Alaska and California sites and the use of AOOS data as one of several potential sources of data to compare changes in air temperature between open-ocean and nearshore locations.

The Gulf of Alaska workshop produced the fewest lesson plans with place-based teaching strategies. Nine lesson plans were produced on the topic of ocean acidification without specific focus on the Gulf of Alaska, despite the place-based emphasis in the scientist's presentation on the potential effects of ocean acidification on the Gulf of Alaska and other high-latitude marine ecosystems. Similarly, a presentation on the use of state-of-the-art

TABLE V: Changes in teacher knowledge, Arctic Ocean workshop.

Responses to "Rate your level of knowledge—Scale 1 (really don't know) to 10 (completely knowledgeable)"	Pretest Average	Posttest Average	Statistical Probability
About the physical and biological processes of the Arctic Ocean	4.0	6.1	0.012
About how Arctic physical and biological processes are changing	3.8	6.6	0.003
About the existing Arctic region flora and fauna	3.9	6.3	0.004
About what impact any changing physical environment will have on Arctic flora and fauna	3.9	6.5	0.006
About the impacts on humans in Arctic communities in the face of change	4.1	7.1	0.000
About traditional ecological knowledge for the Arctic region	2.7	5.4	0.007
About STEM-related careers	4.7	6.4	0.093
About traditional ecological knowledge or culturally relevant knowledge for your region	4.2	6.3	0.072

technology to map the sea floor in Kachemak Bay resulted in six lesson plans about sea floor features, bathymetry, and mapping methods, but only two involved the second place-based strategy of comparisons of data collected in the Gulf of Alaska with data collected in other places. One lesson plan employed the third type of strategy by featuring water sampling at local marine field sites, but regardless of where they were located.

Culturally Responsive Lesson Plans

As shown in Table VII, each of the workshops resulted in the development of some lesson plans with culturally responsive elements. Table VIII shows the number of lesson plans from each workshop with elements in the stages of development along the Level I (emerging) to Level IV (exemplary) continuum for specific standards for culturally responsive educators.

Examples shared here illustrate the kind of lessons that were produced. From the Bering Sea workshop, for example, a collaboration between two elementary-school teachers—one teaching in Alaska and one teaching in Hawaii—involved students in a comparison of the basis for scientific and traditional knowledge taxonomies. The lesson asked students to classify and name sea ice using Inuit terms and to classify rainy conditions using terms in the Hawaiian language. The two teachers demonstrated their proficiency in recognizing the validity and integrity of traditional knowledge systems by providing resources for this work. They also developed a postworkshop pen-pal exchange project between their students, culminating in a field trip for Alaskan students to visit their Hawaiian pen pals, including interactions by students in both classes with Hawaiian scientists and culture bearers. These teaching activities, taken together, placed both teachers at Level IV (exemplary) in cultural responsiveness, defined in the rubric as "fully and fluently engaged in implementing, mentoring, and collaborating." The Hawaiian teacher also collaborated with a second Alaskan teacher and mentored him to incorporate culturally responsive elements in his lesson plan. Finally, she developed a third lesson plan that was responsive to traditional Hawaiian culture by incorporating Hawaiian Elder visits to the classroom and the use of a traditional storytelling technique, "talk story."

An example from the Gulf of Alaska workshop involved an Alaskan elementary-school teacher and two informal educators from Juneau. The lesson plan combined student interviews of long-term community members and Alaska Native Elders, invitations for classroom visits, field trip

TABLE VI: Changes in teacher confidence, Arctic Ocean workshop.

Responses to "Rate your level of confidence—Scale 1 (really don't know) to 10 (completely confident)"	Pretest Average	Posttest Average	Statistical Probability
In being able to teach students about the physical and biological processes of the Arctic Ocean	3.7	6.4	0.004
In being able to teach students about changes occurring with Arctic Ocean physical and biological processes	3.7	6.6	0.002
In being able to teach students about the changes in Arctic region flora and fauna	4.0	6.5	0.012
In being able to teach students about the impacts of change on humans in Arctic communities	4.4	6.9	0.002
In being able to teach students about integrating traditional ecological knowledge with Western science understandings of the Arctic	2.4	5.2	0.003
In being able to teach students about STEM-related careers	4.7	6.3	0.121
In being able to teach students about integrating local, culturally relevant knowledge with Western science understandings	4.2	6.5	0.063

TABLE VII: Results of evaluation of the lesson plans.

	Bering Sea Workshop	Gulf of Alaska Workshop	Arctic Workshop
Lesson plans produced	13	15	7[1]
Teachers who produced lesson plans	7	13	8
Informal educators who produced lesson plans	0	4	0
Scientists who produced lesson plans	1	1	7
Lesson plans indicating application of scientific knowledge	12	15	7[1]
Lesson plans with elements of place-based education	13	6	7[1]
Lesson plans with elements of cultural responsiveness	3	2	7[1]

[1]One lesson plan has not been submitted as final; evaluation is based on a draft.

activities to sample juvenile salmon and trout in a lake, observations of marine fish at a marine lab, and observations and comparisons of traditional Alaska Native fishing gear artifacts in a museum. These educators' proficiency was characterized at Level II (developing) on the culturally responsive continuum.

More culturally responsive lessons emerged from the Arctic Ocean workshop, in part because curriculum alignment with the ILF was required by the NSBSD. As shown in Table IX, six lesson plans included an essential question from the ILF. The grade K–3 lesson plan on bowhead whales, however, was the only one in which students were engaged in activities that required them to demonstrate learning of both scientific and ILF cultural concepts in an integrated way. The bowhead whale has immense traditional and cultural significance to the Iŋ̃upiat, and the annual hunts and celebrations of the harvests are significant community events. The science lesson plan focused on whale anatomy, food habits, and life cycle and incorporated a fall field trip to observe whaling on the ice and the naming of body parts in the Iŋ̃upaq language, as well as English. The teacher outlined a yearlong unit involving classroom visits by both Iŋ̃upiaq Elders and a local whale biologist and involving student participation in community events during spring whaling and harvest celebrations. In contrast, a team consisting of a middle-school science teacher and a language arts teacher produced linked lesson plans about Arctic Ocean food webs. The Arctic food web illustration used for both lesson plans, however, did not include humans, or the Iŋ̃upiat specifically, in the food web. The grade K–3 bowhead whale lesson plan was thus rated, using the rubric, as Level II (developing) in two traits and Level IV (exemplary) in two others. Four other lesson plans scored at Level I (emerging) in four areas of the rubric.

Culturally Responsive Workshop Design and Implementation

The evaluation of the design and implementation of the three workshops demonstrates improvements in performance in terms of modeling culturally responsive instruction (Table X). We rated our performance in the design and implementation of the Arctic Ocean workshop as improving

TABLE VIII: Results of rubric evaluation of cultural responsiveness of lesson plans.[1]

Alaska State Cultural Standard	Bering ($N = 3$)		Gulf ($N = 2$)		Arctic ($N = 7$)	
	No.	Rating Level	No.	Rating Level	No.	Rating Level
A.1	1	III	1	II	1	III
	1	IV			4	I
A.2	1	I	1	II	1	II
A.3	1	I	1	II	1	IV
A.4			1	II	1	II
A.6	1	I			4	I
B.1	2	I			1	III
B.2	1	II	3	II	1	III
B.3			1	I		
B.4	0		0		0	
B.5	1	III	1	III	4	I
					1	IV
C.1	0		0		0	
C.2	1	I	2	I	4	III
	1	IV				
C.3			1	II	1	II

[1]Level I = emerging, Level II = developing, Level III = proficient, Level IV = exemplary.

TABLE IX: Alignment of Arctic Ocean workshop lesson plans with the ILF.[1]

Lesson Plan	Grade Level	Science Topic	Essential Questions from the ILF[2]
Bowhead Whales (Barrow class)	K–3	Similarities and differences of living things, life cycles	How does the Arctic environment affect the choice of skills and technology a person needs?
The Importance of Bowhead Whales to the Iñupiat (Florida class exchange with Barrow class)	Middle school	Whale ecology, impacts of oil development on migratory patterns of Arctic whales	NA, but emphasis on importance of bowhead whales to the Iñupiat
Arctic Smorgasbord	Middle school and up	Food webs, transfer of matter and transformation of energy	What understandings about the nature of food are clarified through the Iñupiaq language?
Understanding the Food Web	Middle school and up	Writing science in the language arts classroom	What understandings about the nature of food are clarified through the Iñupiaq language?
Sea Ice Impact	Middle school and up	Changes in ocean salinity, resulting influence on thermohaline circulation, inquiry	What skills, understandings, beliefs, and values does a person need in order to be a good provider?
Foraging for Fish in a Melting Arctic: The Black Guillemot's Quest to Feed Their Young	Elementary school	Reproduction, adaptation, climate change, inquiry	What are the appropriate ways of protecting and respecting the land, air, and sea and the living things that inhabit them?

[1]NA = not applicable.
[2]Iñupiaq cultural concepts for integration with science education in the school district curriculum.

from Level I to Level IV in four traits and to be at Level III in two other traits. Performance in one area stayed at Level I, and three stayed at Level II. The most important design features that improved cultural responsiveness were the inclusion of community members in the workshop, the inclusion of Alaska Native Elders as coinstructors, the use of the ILF as a traditional knowledge framework, the setting of an Arctic community, and the late May timing with respect to access to shore-fast sea ice and the major cultural seasonal event of spring whaling.

The responses of educators to end-of-the-day surveys during each workshop also provide insight into what they were taking away as their understanding about the importance of culturally responsive education. Each response is from a teacher who participated in the Arctic Ocean workshop:

> *"(It is) important for students from the Arctic to feel like they can retain their traditional knowledge while at the same time learning to 'play the game' with western approaches in order to move everyone forward. Leona (Okakok) offers a good example of someone who can retain their 'anchor' in traditional knowledge while reaching across the gap to western thinkers to move us all forward."* (Day 2 response to the question "What were the big (key) ideas you gained from the panel discussion—Careers in Arctic Ocean Science—conducted this morning?")

> *"This was so fascinating! It was an honor to hear from Leona (Okakok), the perspective of the Iñupiaq traditions, and her vision to bring the cultural traditions to the classroom. I was especially struck by the quote 'No matter where people live they should have books about their culture.' I am interested to hear more about the bridging the ILF and the western standards.… Leona (Okakok) does a terrific job of stating the case for the importance of Native way of knowing and learning."* (Day 3 response to the question "What were the big (key) ideas you gained from the second activity—Inupiaq Learning Framework and the NSBSD Curriculum Process (i.e., Leona Okakok and Peggy Cowan)—conducted this morning?")

> *"The big key ideas I gained from the first activity was the importance of learning from community members, like the local Iñupiat population, that have expertise based on their experiences in the natural world."* (Day 3 response to the question "What were the big (key) takeaway ideas you gained from the activity Resiliency and Change for Arctic People (i.e., Anne Jensen, Robert Suydam, and Matt Druckenmiller)?")

IMPLICATIONS

The workshops took place under logistical constraints that were inherent to the target audiences, the focus on LMEs, and the desire by the partners that scientists have meaningful and effective K–12 science outreach experiences. Workshop organizers designed and implemented the workshops around "best practices" for effective professional development for science, which Wilson (2013) summarized as (1) focusing on specific content, (2) engaging teachers in active learning, (3) enabling the collective participation of

TABLE X: Results of rubric evaluation of cultural responsiveness of workshop design.

Performance Trait	Bering Sea Workshop Rating Level	Gulf of Alaska Workshop Rating Level	Arctic Workshop Rating Level
A.1	I	I	IV
A.2	I	I	IV
A.3	I	I	III
A.4	II	II	II
A.6	II	II	II
B.1	NA	NA	NA
B.2	NA	NA	NA
B.3	I	I	I
B.4	—	—	IV
B.5	I	I	IV
C.2	II	II	III
C.3	I	II	II

[1]NA = not applicable; — = trait not present.

teachers (sometimes administrators), (4) coherence (aligned with other school policy and practice), and (5) sufficient duration (Supovitz and Turner, 2000; Garet et al., 2001; Desimone et al., 2002; Desimone, 2009). The specific content was provided by current research in each ecosystem that had already been conceptualized at the "big picture" level for two of the three ecosystems and that was available through consultation with scientists for the third ecosystem. We engaged educators in active learning by using a variety of interactive methods and achieved collective participation and coherence through the participation of the NSBSD in the Arctic Ocean workshop. The multiday workshop format, however, was still a "one-shot" event, which falls far short of the range of 49 to 80 hours of professional development over the course of a school year that researchers suggest is required to change teachers' conception of the nature of science teaching and learning (Supovitz and Turner, 2000; Garet et al., 2001; Banilower et al., 2007; Yoon et al., 2007). However, the impact of the single workshop was augmented by the inclusion of teachers who had already received related professional development through participation in immersive research experiences and by embedding the Arctic Ocean workshop within the NSBSD's long-term program of professional development related to science curriculum development.

The collaborative nature of the workshops for scientists and educators was aligned with a significant shift in professional development for science teachers and for outreach by scientists that occurred in the last decade. For educators, a shift occurred from content learning to science literacy by involving teachers both as learners and as teachers. This was done by designing professional development around the essential literacy needed by educators to teach the science embodied in the standards. The strategies for this type of professional learning include collaborative structures for teachers and scientists, immersion experiences for teachers in research, and the alignment and implementation of curriculum (Loucks-Horsley et al., 2003). Joyce and Showers (1995) found that using scientists as role models dramatically increased the transfer of knowledge, skills, and application to the classroom. For scientists, the shift that occurred was an increasing emphasis by funders that their research should have an impact beyond the scientific community and that the results should be communicated to nonscientific audiences (e.g., NSF "broader impacts" requirements and NPRB "community involvement" requirements). Inclusion of NPRB, a major funder of marine research in Alaska, and the NSF-funded COSEE-AK and ARCUS in workshop planning and implementation provided the focus on effective science outreach opportunities.

K–12 schools are a logical venue for scientist outreach efforts, particularly in a time of science education reform, but they are a venue where making meaningful contributions is a complicated endeavor. Science educators are seeking current science content but are under increasing pressure to make science relevant to their students in the ever-changing context of standards-based education. Research focused on knowledge interactions between scientists and teachers has identified cultural issues that affect the degree of success. These include the lack of "the scientists' knowledge of classroom realities" and "the perception of scientists having higher status or power in the relationship" (Sussman, 1993; Drayton and Falk, 2006). Several researchers (Caton et al., 2000; Paleaz and Gonzalez, 2002; Ledley et al., 2012) who have evaluated the success of scientist–teacher partnerships reached the conclusion that an important design element for a satisfactory experience by scientists and teachers is a collaborative structure that provides a "level playing field" and a sense of equality between scientists and teachers as professionals. The importance of two-way communication has been emphasized (Caton et al., 2000; Ledley et al., 2012).

We found that the inclusion of scientists and educators in the team that designed and delivered the workshop was an effective strategy to bridge traditional communication gaps between science and education communities. Workshop organizers served as the facilitators, consultants, and planners of the workshop to provide a bridge between the two communities, to support the collaborative structure, and to level the playing field for both educators and scientists as professionals. This approach is aligned with the NSESs for professional development, which stress supporting teachers

as members of a collegial professional community and encouraging collaborations among scientists and teachers with clear respect for the perspectives and expertise of both (NRC, 1996). The inclusion of Alaska Native Elders, educators, and other cultural experts in the planning and delivery bridged the second divide between an indigenous culture and the culture of Western science.

The collaborative development of a product was an important active learning strategy. When teachers create lesson plans, they are empowered to become instructional leaders and facilitators of change, an area of emphasis in the national science standards for professional development (NRC, 1996). Lesson plans also provide a means for immediate feedback to scientists about the application of their outreach. Educators are essentially free-choice learners in a professional development workshop. They learn and implement what is personally and professionally relevant, particularly when the professional development opportunity is being provided by a source or sources beyond their school district. The production and dissemination of the lesson plans was particularly important in the context of Alaska's high turnover rate of teachers in rural communities.

The lesson plans that were an outcome of the Alaska marine ecosystem workshops demonstrated that opportunities for interactions with scientists and the relevance of science to place and culture were influential in what teachers chose to apply in terms of both the content of their lesson plans and the focus of their teaching strategies. The lesson plan development process also changed scientist perceptions about classroom realities. In postworkshop survey comments, they mentioned how this experience contributed to their understanding of the nature of current K–12 education and to their appreciation of the skills required by educators to translate often-complex science into creative activities that enable students of various ages to understand science concepts. Although this was beyond the scope of this project, the effectiveness of this type of relationship in changing teacher practice could be evaluated in the future by surveying teachers and asking them to reflect on teaching the lesson plans, to evaluate their effectiveness, and to describe how they would modify their instruction in light of the evaluations.

Science organizations and institutions often lack the capacity to conduct rigorous research about the educational effectiveness of their outreach efforts to K–12 teachers, and the partners in the ecosystem workshops were no exception. Our results suggest, however, that several workshop design factors can increase the effectiveness of professional development in culturally responsive science: (1) ensuring the relevance of science content to place and culture, (2) encouraging desired instructional practices through modeling, and (3) maximizing the time that educators, scientists, and cultural experts are engaged as members of a collegial professional community. Continuing partnerships between scientists and educators have the potential to sustain the linkages between the scientific and the educational communities.

This approach is transferable to other research projects that have a geographic or ecosystem focus, recognizing that other places will differ significantly from Alaska in terms of the extent to which place and culture are intertwined for its indigenous people who live in rural villages. The production and online dissemination of place-based collaborative lesson plans provide a resource that potentially benefits educators throughout a geographic area and beyond, as is the case for resources for teaching about Alaska marine ecosystems that are of national and global significance. We anticipate additional use of the online lesson plans to address the need identified by Alaska rural teachers for marine science lesson plans and units specific to the Alaskan environment (Anderson and Plude, 2010). They are a source of exemplars of cultural responsiveness for teachers of Alaska Native students. We also anticipate that future curriculum development will result from the scientist–teacher partnerships that began during the workshops and are being sustained. The workshops produced additional products that could be used to develop online, interactive professional development courses and additional opportunities for scientist outreach. In addition, the narrated PowerPoint presentations by the scientists and Iñupiaq educators and Alaska Native Elders could be the basis of a distance-delivered professional development course, with follow-up interactive discussions with the presenters accompanied by dissemination of lesson plans relevant to the scientific concepts presented.

The process of developing the ILF and integrating it into the NSBSD curriculum is an innovative model for other cultural contexts. It was developed at a conceptual level that can be aligned with disciplinary core ideas and cross-cutting concepts in the next-generation science standards framework (NRC, 2012). The emphasis is on ways of knowing, as embodied in the deep understandings that are valued by the specific culture, rather than on a body of specific traditional knowledge. Similar frameworks of knowledge and values for other indigenous cultures could provide a systemic approach to culturally responsive science education and engage learners at this deeper level of cultural relevance.

Lessons Learned About Workshop Design

Formative and summative evaluation assessments from each of the three LME workshops produced these key findings about design principles for integration-focused workshops.

The insights and direct involvement of cultural experts and community members is critical to fostering and supporting culturally responsive science education.

How scientists and Native people come to understand the surrounding natural world is both different and similar (Berkes et al., 2000; Cobern and Loving, 2000; Gagnon and Berteaux, 2009). During the planning and implementation of the ecosystem workshops, developing a bridge for teachers who were from a different culture than their students proved to be a critical design element that required organizers to provide opportunities for respectful consideration of Alaska Native worldviews. The most successful strategy, employed in the Arctic Ocean workshop, was the involvement of Alaska Native Elders who were willing to share traditions and cultural values and who were familiar with Western education and science. In addition, the inclusion of social scientists (i.e., anthropologists) in the workshops supported deeper understandings across cultural boundaries.

Scientists benefited from immersion in K–12 education and in the communities affected by their research.

Our experience confirmed the Loucks-Horsley et al. (2003) description of partnerships between scientists and

teachers as a significant form of professional development for K–12 science teachers that benefits both teachers and scientists. Over the course of the workshops, while teachers deepened their scientific literacy and had the opportunity to enrich their ideas about how science is done in the real world, scientists became more familiar with the needs and realities of a school system and, in the case of the Arctic Ocean workshop, with the needs and realities of an Alaska Native community.

Scientists who participated in the Arctic Ocean workshop expressed changes in their approach to outreach and research in their responses to the last end-of-the-day workshop survey. Responses to the statement "We want to know what concepts or ideas about education, working with teachers, and creating lessons plans that you learned (or gained appreciation for) as a result of this workshop" included the following:

> *"This was great. I learned a lot, how teachers would really do it within their classroom.... Education focuses on concepts, then specifics, with a path to results, all enclosed in standards for measuring learning. Creativity for teaching requires enthusiasm, time, and interactions with a variety of people, so bringing scientists and teachers together periodically is extremely valuable."*

> *"The ILF framework and the history of native Alaskan education were new to me, as were the science requirements for teachers and how tied they are to a mandated curriculum.... A key lesson was that we need to put our science into a larger framework, whether it's the ILF or national science standards. It's important to keep our eyes on the bigger picture. I loved the idea of thinking about what should an 18-year-old person understand. I suppose educators think about that all the time, but it isn't a common exercise for a scientist/researcher. I appreciated that we need to put our science into their world and explain as fundamental concepts of use to everyone."*

Responses to other questions include the following:

> *"I think having teachers from all levels of education in K–12 in one workshop is very good. It was interesting to see the levels of lesson planning for the different age classes, moving from fun knowledge to complexity and entertainment. The success of learning is very dependent on the educators' willingness to take on new tasks, interact with players normally outside their field of expertise, and take on the extra effort to make the lessons proactive for the students."* (Response to the question "Do you have any specific feedback about any of the lessons shared this afternoon?")

> *"It was a good idea to present the local challenges and approaches to curriculum and teaching. Giving voices to elders as part of the workshop was great and shows the commitment of presenting sciences and culture interconnected.... I am interested to hear more about bridging the ILF and the western standards. I think it is great to start with the big concepts and questions and have the units and activities come out of that."* (Response to the question "One of the lessons presented—the Black Guillemot activity—involved a modeling of a lesson as might be presented to students. Was that helpful and if so why?")

> *"I definitely feel my time was well spent. The interactions will be recalled often during the coming field season and help me remember why it is important to do the research for a number of reasons including getting the information out to K–12 students."* (Response to the question "Did you feel your time was well spent?")

Taking educators and scientists into the "field" makes cultural experiences and cultural and science learning more relevant and exciting.

Taking the workshop participants into a community that is directly dependent on local resources of a surrounding ecosystem has the potential to broaden the worldview of both educators and scientists. Just as a direct connection with scientists in the type of environment where they conduct their research can make science practices more tangible, firsthand experience with indigenous people and the natural world in which they live can make traditional knowledge immediately relevant.

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REFERENCES

Aikenhead, G. 1996. Science education: Border crossing into the subculture of science. *Studies in Science Education,* 27:1–52.

Aikenhead, G. 1997. Toward a First Nations cross-cultural science and technology curriculum. *Science Education,* 81(2):217–238.

Alaska Department of Commerce and Economic Development (ADCED). 2010. Community profiles. Available at http://www.commerce.state.ak.us/dca/commdb/cf_comdb.htm (accessed 22 September 2013).

Alaska Department of Education and Early Childhood Development (ADEED). 2006. Alaska standards: Content and performance standards for Alaska students, 4th ed., revised March 2006. Available at http://www.eed.state.ak.us/standards/pdf/standards.pdf (accessed 22 September 2013).

Alaska Department of Education and Early Childhood Development (ADEED). 2012a. Alaska's public schools: 2011–2012 report card to the public. Available at http://education.alaska.gov/reportcard/2011–2012/reportcard2011-12.pdf (accessed 22 September 2013).

Alaska Department of Education and Early Childhood Development (ADEED). 2012b. Guide to implementing the Alaska cultural standards for educators. Available at http://www.eed.state.ak.us/standards/pdf/cultural_standards.pdf (accessed 22 September 2013).

Alaska Native Knowledge Network (ANKN). 1998. Alaska Rural

Systemic Initiative: Year 3 annual progress report. Education Resources Information Center Reproduction Service No. ED443603.

Anderson, A., and Plude, D. 2010. Needs assessment of Alaska teachers. Alaska Center for Ocean Science Educational Excellence. Available at http://www.coseealaska.net/files/alaska/FinalAKNeedsAssessment.pdf (accessed 22 September 2013).

Banilower, E.R., Heck, D.J., and Weiss, I.R. 2007. Can professional development make the vision of the standards a reality? The impact of the National Science Foundation's Local Systemic Change Through Teacher Enhancement Initiative. *Journal of Research in Science Teaching,* 44:375–395.

Barnhardt, R. 2007. Creating a place for indigenous knowledge in education: The Alaska Native Knowledge Network. Available at http://www.ankn.uaf.edu/curriculum/articles/raybarnhardt/pbe_ankn_chapter.html (accessed 12 November 2013).

Barnhardt, R., and Kawagley, A.O. 2010. Culture, chaos, and complexity: Catalysts for change in indigenous education. *In* Barnhardt, R., and Kawagley, A.O., eds., Alaska Native education: Views from within. Fairbanks, AK: Alaska Native Knowledge Network, Center for Cross-Cultural Studies, pp. 199–216.

Berkes, F., Colding, J., and Folke, C. 2000. Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications,* 10(5):1251–1262.

Blank, R.K., and de las Alas, N. 2009. Effects of teacher professional development on gains in student achievement: How meta-analysis provides scientific evidence useful to education leaders. Washington, DC: Council of Chief State School Officers.

Boyer, P. 2006. Building community: Reforming math and science education in rural schools. Fairbanks, AK: Alaska Native Knowledge Network, Center for Cross-Cultural Studies.

Caton, E., Brewer, C., and Brown, F. 2000. Building teacher–scientist partnerships: Teaching about energy through inquiry. *School Science and Mathematics,* 100(1):7–15.

Cobern, W.W., and Loving, C.C. 2000. 3.3 defining "science" in a multicultural world. *Science Education,* 85:50–67.

Desimone, L.M. 2009. Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher,* 38:181–199.

Desimone, L.M., Porter, A., Garet, M.S., Yoon, K.S., and Birman, B.F. 2002. Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Education Evaluation and Policy Analysis,* 24:81–112.

Drayton, B., and Falk, J. 2006. Dimensions that shape teacher–scientist collaborations for teacher enhancement. *Science Education,* 90(4):734–761.

Gagnon, C.A., and Berteaux, C. 2009. Integrating traditional ecological knowledge and ecological science: A question of scale. *Ecology and Society,* 14(2):26.

Garet, M.S., Porter, A.C., Desimone, L., Birman, B.F., and Yoon, K.S. 2001. What makes professional development effective? Results from a national sample of teachers. *Journal of American Educational Research,* 38:915–945.

Hill, A., Hirshberg, D., Lo, D.E., McLain, E.A., and Morrotti, A. 2013. Alaska's university for Alaska's schools 2013. Anchorage, AK: Center for Alaska Education Policy Research, University of Alaska. Available at http://www.alaska.edu/files/shapingalaskasfuture/SB2412012-2013-.pdf (accessed 22 September 2013).

Joyce, B., and Showers, B. 1995. Student achievement through staff development. White Plains, NY: Longman.

Ledley, T.S., Taber, M.R., Lynds, S., Domenico, B., and Dahlman, L. 2012. A model for enabling an effective outcome-oriented communication between the scientific and educational communities. *Journal of Geoscience Education,* 60:257–267.

Levine, R., González, R., and Martínez-Sussmann, C. 2009. Learner diversity in Earth system science. Paper prepared for the Committee for the Review of the NOAA Education Program. Washington, DC: National Research Council.

Loucks-Horsley, S., Love, N., Stiles, K., Mundry, S., and Hewson, P.W. 2003. Designing professional development for teachers of science and mathematics, 2nd ed. Thousand Oaks, CA: Corwin Press.

National Research Council (NRC). 1996. National Science Education Standards. Washington, DC: National Academies Press.

National Research Council (NRC). 2012. A framework for K–12 science education: Practices, cross-cutting concepts, and core ideas. Washington, DC: Board of Science Education, National Academies Press. Available at http://www.nap.edu/catalog.pjp?record_id = 13165 (accessed 22 September 2013).

National Science Foundation (NSF). 2007. Broader impacts criterion. Available at http://www.nsf.gov/pubs/2007/nsf07046/nsf07046.jsp (accessed 22 September 2013).

North Pacific Research Board (NPRB). 2008. Bering Sea Integrated Ecosystem Research Program hypotheses. Available at http://bsierp.nprb.org/focal/hypotheses.html (accessed 22 September 2013).

North Pacific Research Board (NPRB). 2010. Gulf of Alaska Integrated Ecosystem Research Program overarching questions and hypotheses. Available at http://gulfofalaska.nprb.org/GOAStudyHypObj.html (accessed 22 September 2013).

North Slope Borough School District (NSBSD). 2010. Mapgkuqput Iñuuniagnigmi: Iñupiaq learning framework. Barrow, AK: NSBSD. Available at http://www.nsbsd.org/Page/687 (accessed 22 September 2013).

Ogawa, M. 1995. Science education in a multiscience perspective. *Science Education,* 79:593.

Okakok, L. 2010. Serving the purpose of education. *In* Barnhardt, R., and Kawagley, A.O., eds., Alaska Native education: Views from within. Fairbanks, AK: Alaska Native Knowledge Network, Center for Cross-Cultural Studies, pp. 99–118.

Paleaz, N.J., and Gonzalez, B.L. 2002. Sharing science: Characteristics of effective scientist–teacher interactions. *Advances in Physiology Education,* 26:158–167.

Pandya, R.E. 2012. A framework for engaging diverse communities in citizen science in the U.S. *Frontiers in Ecology and the Environment,* 10:314–317.

Riggs, E.M. 2005. Field-based education and indigenous knowledge: Essential components of geoscience education for Native American communities. *Science Education,* 89(2):296–313.

Semken, S. 2005. Sense of place and place-based introductory geoscience teaching for American Indian and Alaska Native undergraduates. *Journal of Geoscience Education,* 53(2):149–157.

Snively, G., and Corsiglia, J. 2001. Discovering indigenous science: Implications for science education. *Science Education,* 85(1):6–34.

Supovitz, J.A., and Turner, H.M. 2000. The effects of professional development on science teaching practices and classroom culture. *Journal of Research on Science Teaching,* 37:963–980.

Sussman, A., ed. 1993. Science education partnerships: Manual for scientists and K–12 teachers. San Francisco, CA: University of California.

Wiggins, G., and McTighe, J. 2005. Understanding by design, expanded 2nd ed. Alexandria, VA: Association for Supervision and Curriculum Development.

Wilson, S.M. 2013. Professional development for science teachers. *Science,* 340(6130):310–313.

Yoon, K.S., Duncan, T., Lee, S.W.-Y., Scarloss, B., and Shapley, K. 2007. Reviewing the evidence on how teacher professional development affects student achievement. Issues & Answers Report, REL 2007, No. 033. Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Southwest.